(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 June 2001 (14.06.2001)

PCT

(10) International Publication Number
WO 01/42693 A2

(51) International Patent Classification⁷: F16K

(21) International Application Number: PCT/US00/42566

(22) International Filing Date: 5 December 2000 (05.12.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/170,030 10 December 1999 (10.12.1999) US
60/171,174 16 December 1999 (16.12.1999) US
09/684,537 6 October 2000 (06.10.2000) US

(71) Applicant *(for all designated States except US)*: **BARROW FINANCIAL ASSOCIATES** [—/US]; 3506 East Highway 16, P.O. Box 99, Sharpsburg, GA 30277 (US).

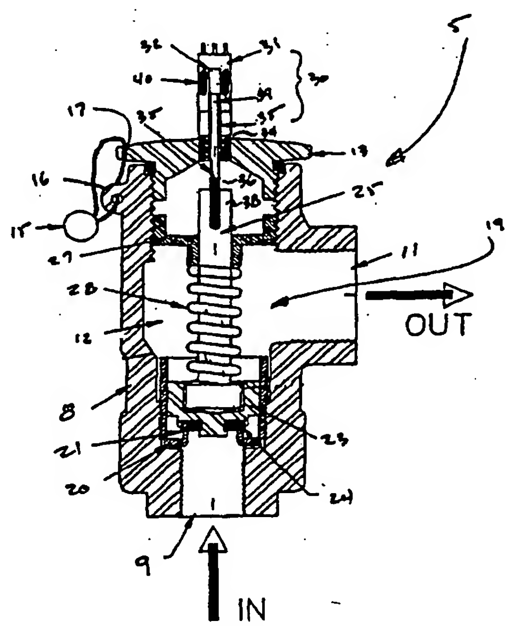
(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **BARROW, William, E.** [—/US]; 20 Mattox Road, Newnan, GA 30263 (US). **BARROW, Michael, A.** [—/US]; 120 Riverside Court, Sharpsburg, GA 30277 (US). **BYRD, David, E.** [—/US]; 440 McBride Road, Fayetteville, GA 30215 (US).

(74) **Agents: FAILS, Charles, H.** et al.; Needle & Rosenberg, P.C., Suite 1200, 127 Peachtree Street, N.E., Atlanta, GA 30303-1811 (US).

(81) **Designated States** *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

*[Continued on next page]*

(54) Title: PRESSURE RELIEF VALVE DETECTION AND MONITORING DEVICE AND SYSTEM




(57) Abstract: A pressure relief valve detection and monitoring device, system, and method are disclosed. The device includes a pressure relief valve having a valve assembly. The valve assembly has a first closed position, and at least one open position in which fluid is permitted to pass through the valve. A valve position monitoring device is disposed on the valve body and is adapted to generate a position signal when the valve assembly is moved into the at least one open position. The monitoring device includes a housing mounted on the valve body, and an actuating mechanism positioned with respect to the housing and is adapted to move with respect to the housing in response to the movement of the valve assembly from its closed position into its at least one open position. In a first embodiment the valve position monitoring device comprises a linear variable differential transformer adapted to emit a second position signal in response to the valve being moved into the at least one open position.

*[Continued on next page]*

WO 01/42693 A2

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published:**

— *Without international search report and to be republished upon receipt of that report.*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

In a second embodiment the valve position monitoring device comprises a reed switch adapted to signal when the valve assembly is moved out of its closed position. In a third embodiment the valve position monitoring device comprises a linear potentiometer adapted to emit a second position signal in response to the valve being moved into the at least one open position.

# PRESSURE RELIEF VALVE DETECTION AND MONITORING DEVICE AND SYSTEM

## CROSS REFERENCE TO RELATED APPLICATIONS

This international patent application claims priority to U.S. Patent Application Number 60/170,030 filed on December 10, 1999, to U.S. Patent Application Number 60/171,174 filed on December 16, 1999, and to U.S. Patent Application Number 09/684,537 filed on October 6, 2000, respectively.

## FIELD OF THE INVENTION

In general, the invention relates to pressure relief valves used in pressurized fluid distribution systems. More particularly, the invention relates to a pressure relief valve detection and monitoring device, system, and method for monitoring and reporting the status of a pressure relief valve or valves used with the fluid distribution system.

## BACKGROUND OF THE INVENTION

In a great majority, if not all, of the various types of pressurized fluid and/or process systems in usage it is common that at least one pressure relief valve be provided to relieve any "over-pressure" or high pressure conditions that may occur within the system. This is done, as is known, in order to prevent a possible rupture or failure of the pressure vessels and/or piping provided as a part of the fluid distribution system. Examples of the known types of pressurized fluid distribution systems with which relief valves are used include steam, water, and gas distribution systems, and also include pressurized mechanical refrigeration systems, such as those which may use a ammonia as a refrigerant.

The pressure relief valves are constructed to provide emergency relief from excess pressure build up in the fluid system, and are built in strict conformance with the boiler and pressure vessel code requirements of the

American Society of Mechanical Engineers for such safety relief devices. The capacity of each pressure relief valve is also rated by the National Board Boiler and Pressure Vessel Inspectors. Each valve is accurately set and sealed by qualified technicians at the facility in which the valves are manufactured, and is also typically manufactured to be tamper resistant.

Once installed, a properly specified pressure relief valve is provided for venting to atmosphere, or into any other approved capture or containment vessel, any fluid which exceeds the design pressure of the fluid distribution system. Once the relief valve discharges fluid therethrough, the valve will attempt to reseat itself in order to stop fluid loss once system pressure falls to within the nominal design or working pressure range. However, once the relief valve has discharged, it is common practice, and in many instances is required, that the valve be replaced in that dirt or debris may have settled in the valve seat during the over-pressure event such that the valve may not reseat properly. Also, once the valve has been operated the possibility exists that due to the flexing of the valve seat compression spring, it is not known if the valve will properly relieve the next over-pressure event at the designed or specified pressures. Accordingly, relief valves are typically intended for a one-time use, and are replaced after discharge due to the aforementioned problems.

In usage, particularly where more than one valve is used as a part of the system, it is typical that each valve will be piped into a common collection header provided as a part of a spill/overflow collection system. The problem that occurs in this instance, however, is determining the location and/or identity of the valve that has relieved in an over-pressure situation so that the valve may be replaced if necessary. This is extremely problematic where several relief valves are provided as a part of a complex pressurized fluid distribution system, for example in a manufacturing or process setting, in which it may be impossible to determine exactly which one, or ones, of the pressure relief valves discharged. There is a need,

therefore, for a pressure relief valve detection and monitoring device, and system, which will identify the specific relief valve, or valves, which have relieved when an over-pressure event or events occur within the fluid distribution system.

With regard to commercial or industrial pressurized refrigeration systems, which systems commonly use ammonia as a refrigerant, current federal, state, and/or local laws and regulations require that the system user notify the appropriate authorities when more than 100 pounds of ammonia has been discharged to atmosphere. With the know types of pressure relief valves, however, aside from problems in determining if a valve has relieved in an over-pressure event, the amount of fluid that has been relieved from the system cannot be accurately determined or reported. There is a need, therefore, for a pressure relief valve detection and monitoring device and system which will not only detect that an over-pressure relief event has occurred, but which is also adapted for determining the volume of fluid that has been discharged from the system during the over-pressure event.

In addition, there is a phenomenon common to pressurized fluid systems known as relief valve "simmer" or "seepage", in which some of the fluid passes in almost imperceptible levels through the relief valve. This phenomenon typically will occur when the fluid pressure within the system comes to within 10% of the pressure relief setting of the valve. At these pressure levels, it is not uncommon for the fluid pressure to force the piston of the valve assembly upwardly off of the valve seat ever so slightly, which allows the fluid to seep through the valve and discharge to atmosphere and/or into the fluid collection system. Thus, there is a need for a pressure relief valve detection and monitoring device and system which can detect when simmering in the relief valve occurs, which event is typically impossible to otherwise detect, such that the pressure relief valve can be replaced if need be, and/or the fluid over-pressure situation can be detected

and the cause determined prior to a complete system "full blow" event in which a mass amount of the fluid is discharged to atmosphere with potentially harmful effect to person and property.

Devices adapted for use in monitoring the position of valves exist. These devices include U.S. Patent No. 3,896,280 to *Blake* which discloses a valve position indicator device for indicating to a driver or a mechanic an open relief valve condition resulting from a clogged or plugged engine oil filter. United States Patent No. 5,333,642 to *Kemp et al.* discloses a safety valve monitoring apparatus which uses a magnetic ball that is moved from a home position when the relief valve opens.

Other devices are disclosed in U.S. Patent No. 5,620,024 to *Yonezawa* which discloses a relief valve operation detector having an operation member adapted to be moved when the relief valve is actuated so that a detected portion is moved away from a detecting portion to signal the operation of the valve; U.S. Patent No. 5,926,018 to *Jones* which discloses a proximity switch comprised of a magnetic sensor for sensing the reciprocation of a spool within a lubricating distributor block; U.S. Patent No. 4, 287,432 to *Sensibar* which discloses a valve position detecting apparatus for determining the position of a hopper valve within a barge or a dredge; and U.S. Patent No. 5,673, 563 to *Albertson et al* which discloses a pressure relief apparatus for a refrigeration system in which the fluid released from the valve is accumulated in a passageway provided as a part of the valve, and sensed by a sensor positioned therein.

As described above, what is needed, but apparently unavailable in these devices, is a pressure relief valve detection and monitoring device and system which will identify the location of the pressure relief valve or valves that have opened from a closed or seated position, whether as a result of simmer or from a full blow of the system, as well as such a device and system which will measure the degree to which the relief valve was open

during an over-pressure event, the duration thereof, and to determine and report the volume of fluid that passed through the relief valve during the over-pressure event.

## SUMMARY OF THE INVENTION

The present invention provides an improved pressure relief valve detection and monitoring device, system, and method adapted for use with pressurized fluid distribution systems for detecting the opened/closed state, and monitoring the performance of, at least one pressure relief valve provided as a part of the fluid system, and which also overcome some of the design deficiencies of the art. The pressure relief valve detection and monitoring device, system, and method of this invention provide a simple and efficient solution to the problem of determining the identity of the pressure relief valve, or valves which have opened in an over-pressure event, and whether the valve properly closes thereafter. Moreover, the relative simplicity of this invention, coupled with its ease of use, provides a greater degree of reliability in addressing the problems of efficiently and effectively monitoring the performance of a pressure relief valve or valves within a fluid distribution system.

This invention attains this degree of flexibility, as well as simplicity in design and construction, by providing a valve body having an inlet port and a spaced outlet port, each of which is separately defined within the valve body, and a fluid flow path also defined within the valve body and extending from the inlet port to the outlet port thereof, respectively. A valve assembly is housed within the valve body and is positioned within the fluid flow path such that the valve assembly has a first closed position in which fluid does not flow through the valve body, and at least one open position in which fluid is permitted to pass through the valve body. The at least one open position of the valve assembly may comprise a range of open positions. The device

also includes a valve position monitoring device disposed on the valve body, the monitoring device being constructed and arranged to generate a position signal when the valve assembly has moved into its at least one open position.

The monitoring device comprises a housing mounted on the valve body, and an actuating mechanism positioned with respect to the housing, the actuating mechanism being constructed and arranged to move with respect to the housing in response to the movement of the valve assembly from its closed position into its at least one open position. The actuating mechanism may comprise an elongate rod operably coupled to the valve assembly, which rod extends at least partially within the housing and is supported for movement therein.

In a first embodiment, the housing may itself comprise a linear variable differential transformer constructed and arranged to emit a first position signal when the valve assembly is in its closed position, and to emit at least a second position signal when the valve assembly is moved into at least one open position. The transformer is constructed and arranged to emit the at least one second position signal as a proportionate signal correlating to the position of the valve assembly in its at least one open position with respect to the first position of the valve assembly so that the degree to which the valve assembly of the relief valve has been opened can be measured.

In a second embodiment a ferrous metal core formed as a part of or positioned on the rod acts in concert with a reed switch positioned on the housing. The reed switch is held in a first position when the valve assembly is in its closed position, and is constructed and arranged to be moved into a second position in response to the movement of the metal core in close proximity thereto, which occurs in response to the movement of the valve

assembly into its at least one open position, and to emit the position signal in response to being moved into this second position.

In a third embodiment, the housing comprises a linear potentiometer constructed to emit a first position signal when the valve assembly is in its closed position, and to emit at least a second position signal when the valve assembly is moved into at least one open position. The linear potentiometer is constructed to emit the second position signal as a proportionate signal which correlates to the position of the valve assembly in its at least one open position with respect to the first position thereof so that the degree to which the valve assembly of the relief valve has been opened can be measured.

The pressure relief valve detection and monitoring system comprises a pressure relief valve and a valve position monitoring device as described above, plus a control system operably coupled to the valve position monitoring device. The control system is constructed and arranged to compare the second position signal to the first position signal for determining the extent to which the valve assembly has opened in response to the flow of fluid therethrough. The control system is also constructed and arranged to measure the period of time during which the valve assembly is in its at least one open position, and to determine the rate of fluid flow therethrough during this time period. Accordingly, the control system is also constructed and arranged to determine the volume of fluid that has passed through the valve assembly during the time in which the valve assembly is in its at least one open position.

The pressure relief valve detection and monitoring system may also comprise at least one data input device, at least one data storage and retrieval device, a data display device, and an annunciator, each of which is operably coupled to a controller provided as a part of the control system.

An improved method of monitoring a pressure relief valve used in a pressurized fluid system results from the aforesaid system and device, the method including the steps of generating a first or base position signal with the valve position monitoring device when the valve assembly is in its closed position, monitoring the position of the valve assembly, and generating at least a second position signal in response to the movement of the valve assembly into its at least one open position.

The method may also comprise the steps of continuously monitoring the position of the valve assembly, as well as continuously reporting the at least a second position signal to a controller. The steps of recording the duration of the time period during which the valve assembly is in its at least one open position, determining the flow rate during this time period, as well as determining the volume of fluid passed therethrough, may also be performed as a part of this method.

It is to these objects, as well as the other objects, features, and advantages of the present invention, which will become apparent upon reading the specification, when taken in conjunction with the accompanying drawings, to which the invention is directed.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side elevational view of a first embodiment of the pressure relief valve detection and monitoring device of the invention.

Fig. 2 is a side elevational view in cross-section of the device of Fig. 1.

Fig. 3 is a side elevational view of a second embodiment of the pressure relief valve detection and monitoring device of the invention.

Fig. 4 is a side elevational view in cross-section of the device of Fig. 3.

Fig. 5 is a process flow chart of the method of the invention.

Fig. 6 is a flow chart of a fluid flow rate subroutine performed as a part of the process of Fig. 5.

Fig. 7 is a schematic illustration of the pressure relief valve detection and monitoring system of the invention.

Fig. 8 A is a side elevational view in cross-section of a third embodiment of the pressure relief valve detection and monitoring device of the invention.

Fig. 8 B is an enlarged fragmentary view of the linear potentiometer of the pressure relief valve detection and monitoring device of Fig. 8 A.

## DETAILED DESCRIPTION OF THE INVENTION

Referring now in detail to the drawings, in which like reference characters indicate like parts throughout the several views, a first embodiment of a pressure relief valve monitoring device 5 of the invention is disclosed. The device comprises a pressure relief valve 7 having a valve body 8, with an inlet port 9 and spaced outlet port 11 separately defined therein. Also defined within the valve body is a continuous fluid flow path 12 in communication with the inlet and outlet ports, respectively. A threaded cap 13 is threadedly received at an upwardly extending end portion of the valve body, in a threaded barrel-like portion projecting upwardly from the valve body, as best shown in Fig. 2.

In known fashion, a seal 15 is provided for ensuring that once the cap 13 is threadedly affixed to the valve body 8, that the valve is not otherwise tampered with or adjusted to ensure that the valve remains set for the proper pressure relief point. The seal, accordingly, has an elongate wire passed or looped through an opening defined in an ear 16 formed as a part of the valve body, and an opening 17 (Fig. 2) defined in the cap, with both ends of the wire being brought and joined together by a deformable lead seal, or other known type of seal, which can be removed only by being

permanently destroyed to indicate that the valve may have been internally adjusted or tampered with.

As best shown in Fig. 2, a valve assembly 19 is disposed within the valve body, and is situated within the fluid flow path for opening and closing the valve. The valve assembly includes a valve seat insert 20 threadedly fitted within the valve body, and valve seat 21 formed thereby. A piston 23, having a piston seat 24, is sized and shaped to move in reciprocating fashion within the valve body. The piston is affixed to a proximal end of an elongate piston guide stem 25, the distal end of which is passed through and received within an adjusting gland 27 for guiding the movement of the piston within the valve body. A compression spring 28 is positioned about the piston guide stem and bears against the adjusting gland and an end of the piston guide stem so that the piston guide stem forces the piston and piston seat down into sealed, seated engagement with the valve seat 21. The valve seat is preferably manufactured of a durable, rigid, metallic material, for example steel. The piston seat 24 is typically comprised of a resilient or plastic material, which may include Teflon® or other suitable valve seat materials intended for use in sealing pressure relief valves.

In known fashion, the tension of the spring 28 is adjusted by threadably moving the adjusting gland 27 in the axial direction of the piston guide stem toward and away from the piston 23 so as to vary the compressive force of the spring bearing against the piston. The adjusting gland 27 is typically pre-set at the manufacturing facility in which the relief valve is produced such that once the adjusting gland is set, and the cap 13 is threadedly affixed to the barrel of the valve body, the piston is properly seated and sealed such that the pressure relief setting of the valve may not otherwise be adjusted.

The pressure relief valve 7 described hereinabove is itself a conventional relief valve, and may include those relief valves manufactured

by Hansen Technologies, Inc. as well as those from the several manufacturers of such valves. As such, the material composition, the construction, and the operation of the relief valve are not described in further detail as this information is well within the knowledge of those skilled in the art.

Referring now to Figs. 1 and 2, this embodiment of the relief valve monitoring device 5 includes a detection assembly 30 comprised of an elongate housing 31 affixed to the cap 13 of the valve body. The housing has an elongate bore or chamber 32 defined therein and extending for substantially the length thereof. The opening defined in the housing at the end of the bore is placed in registry with an opening 34 defined in the cap 13. An elongate actuating rod 35 is operably coupled to the piston guide stem by threading one of the ends 36 of the rod into a threaded end 38 of the piston guide stem 25. The rod 35 may be otherwise and conventionally affixed or fastened to the end of the piston guide stem passed through the adjusting gland. For example the rod may be received in the end of the guide stem and secured therein by epoxy or other suitable adhesives, or it may be soldered into position. A ferrous or metal core 39 is in turn positioned at the end of the rod 35 opposite the piston guide stem so that the metal core rides, *i.e.* it moves linearly, within and at least partially along the length of the bore 32 defined within the housing 31. The metal core may be formed as a part of the rod 35, it may be threadedly affixed thereto, or it may be secured to the end of the rod by epoxy or other suitable adhesives, as desired.

Although not illustrated in Figs. 1 and 2, it is anticipated that a bore liner or guide may be provided for ensuring that the rod 35 and the core 39 are guided for linear movement in the axial, or longitudinal, direction of the piston guide stem within the housing 31. Although shown in Figs. 1 and 2 as being coaxially aligned with the axis of the piston guide stem 25, and the

axis of piston 23, it is anticipated that the rod 35 and the metal core 39 need not be positioned coaxially with respect thereto, just that they be operably coupled to the piston guide stem so that as the piston 23 moves from its closed to at least one open position thereof, the closed position being shown in Fig. 2, that the rod 35 will be linearly actuated or moved and will in turn linearly actuate, *i.e.* move, the metal core 39 within or with respect to the housing 31 for the reasons described below.

The valve assembly 19 is constructed and arranged to move into at least one open position in response to the release of fluid pressure through the valve, which occurs when the fluid pressure has enough force to unseat the piston 23 from the valve seat 21, and against the compressive force of the spring 28. Thus it is possible, and it is anticipated, that the valve/valve assembly will have a range of open positions, which open positions will be proportionate to the force of the fluid passed/released through the relief valve. In this manner, the valve assembly will have at least one open position, the at least one open position comprising a range of open positions.

Still referring to Figs. 1 and 2 and as best shown in Fig.2, the housing 31 in this embodiment of the device 5 comprises a linear variable differential transformer 40 formed as a part of and extending substantially the length of the housing. The transformer 40 is a conventional linear variable differential transformer, hereinafter referred to as a "LVDT" transformer, which may include those devices manufactured by RDP Electrosense, Inc., among others.

As described above, the piston guide stem 25 is passed through the adjusting gland 27 such that the core extender rod 35, which is formed or affixed to the top, or free end, of the piston guide stem protrudes through the hole or opening 34 defined in the cap 13, and extends at least partially into and along the length of the bore 32 defined within the housing 31. The

housing comprises the LVDT, and is mounted to the cap. The cap in turn is affixed the body of the relief valve, and the core extender rod positions the metal core 39, preferably a ferrous/metallic material having magnetic properties, within the bore of the LVDT transmitter body.

An electrical potential is provided to the LVDT body windings by the positioning of the metal core within the bore/LVDT. The LVDT is powered by a suitable power source 138 (Fig. 7), so that the LVDT in association with the core 39 develops an output signal of a first frequency and amplitude. When the metal core 39 is in the closed or base position of the valve assembly 19 as shown in Fig. 2, the position signal will thus have a specific frequency and amplitude, or "signature." When, and if, the metal core moves within the housing/transformer, which occurs when the piston 23 and the piston guide stem 25 move along their longitudinal axes away from the valve seat 21 to allow pressurized fluid to pass through the valve body during a over-pressure event, for example, into “at least one open position”, the core changes its proximity to the LVDT windings and thus creates a change in the output frequency and amplitude measured by the LVDT, which has the effect of creating a unique position signal separate and apart, *i.e.* distinct, from the base position signal.

By establishing a base position signal, therefore, any movement of the core 39 with respect to the housing 31 and the transformer 40 formed as a part thereof, resulting from the movement of the piston guide stem and the piston, can be detected and measured with a degree of accuracy heretofore unknown in the art. Although not shown in Figs. 1 and 2, the housing 31 of the detection assembly 30 is affixed to the cap 13 by any conventional manner, which may include the use of a thread formed on the housing and a complimentary thread or collar formed on the cap 13, by soldering the housing thereon, or by any other known means of securing a housing to the top of a valve.

A second embodiment of the pressure relief valve monitoring device 55 of this invention is illustrated in Figs. 3 and 4. Again, the device 55 includes a pressure relief valve 57 having a valve body 58 with an inlet port 59 defined therein, and a spaced outlet port 61 also defined therein. A fluid flow path 62 is defined, and extends, within the valve body, and is in communication with the respective ports 59, 61. A cap 63 is threadedly affixed to the valve body at an upwardly extending barrel-like portion, as best shown in Fig. 4.

A valve assembly 69 is supported within the fluid flow path of the valve body, and is shown in its closed position in Fig. 4. The valve assembly is adapted for moving into at least one open position, and preferably a range of open positions proportionate to the pressure of the fluid being passed therethrough in the event of an over-pressure event, as described above. The valve assembly 69 includes a valve seat 71 positioned within the valve body. The piston 73 has a piston seat 74 received on the valve seat, and has an elongate piston guide stem 75 projecting in a longitudinal/axial direction toward and through an adjusting gland 77 constructed in fashion identical to the adjusting gland 27 of Figs. 1 and 2. Again, a spring 78 is disposed about the piston guide stem 74 and bears against the adjusting gland and an end of the guide stem to force the piston and piston seat into engagement with the valve seat 71 in order to seal the piston within the fluid flow path so that fluid does not ordinarily pass through the relief valve. The pressure relief valve 57 and the valve assembly 69 provided as a part thereof are otherwise conventional, and thus are not described in greater detail as their construction and use is well known to those of skill in the art.

A detection assembly 80 is provided as a part of the pressure relief valve monitoring device 55. The assembly 80 includes an elongate housing 81, and a reed switch 90 mounted thereon. The housing has an elongate

bore or chamber 82 defined therein which extends for substantially the length of the housing. The bore 82 is in axial alignment with an opening 84 defined within the cap 63, such that an elongate metal actuating rod 89, which rod is threadedly affixed to the piston guide stem 75, is extended therethrough and extends at least partially into the bore of the housing. As shown in Fig. 4, the actuating rod has a metal core 89' formed as a part thereof, which core comprises a ferrous metallic material. The rod/core is positioned with respect to and in close proximity to the reed switch 90 positioned externally on the housing 81. The metal core may, if so desired be affixed to the rod 89 in fashion similar to the construction of the rod 35 and the core 39 of the device illustrated in Figs. 1 and 2, rather than being formed as a part of the rod.

As shown in Fig. 4, when in its base or closed position, the actuating rod/core 89, 89' is positioned adjacent the reed switch 90 such that the reed switch is held in a closed position. When the piston 73 moves in the longitudinal axial direction of the piston guide stem 75 into at least one open position, this again being a range of positions based proportionately on the pressure of the fluid passed through the valve assembly and the valve body, the metal core 89' is moved away from the reed switch 90 such that the contacts open to indicate that the relief valve has been moved into an open position.

Unlike the first embodiment of the pressure relief valve monitoring device 5 shown in Figs. 1 and 2, this embodiment of the pressure relief valve monitoring device does not measure the degree to which the piston 73, *i.e.* the valve assembly 69, has been opened, rather it detects that the switch/piston has moved from its base or closed position into an open position. The reed switch 90 is not constructed to function as a linear variable differential transformer in that it does not emit a proportionate signal based on the position of the rod 89 or the core 89' with respect to the reed

switch. Other devices, including, but not limited to, a capacative switch, a mercury switch, an analog or digital relay, or a snap switch may be used in place of the reed switch if so desired, each such device having the same functional purpose of the reed switch, namely having a first and a second signal generating position correlating to the position of an actuating device, such as the rod 89.

Fig. 5 is a flow chart of the process employed by the pressure relief valve monitoring device of this invention. The flow chart illustrates the process followed by the first embodiment of the pressure relief valve monitoring device 5, as well as the process employed by the second embodiment of the pressure relief valve monitoring device 55, based on its simpler construction.

Referring now to Fig. 5, the process is started in step 101 by polling the detection assembly 30, 80, respectively, as to whether the valve assembly 19, 69, respectively, is in a closed or open position. If the valve is closed, as determined in step 102, the process loops back on itself to step 101 and will continue looping in this manner from step 101 to step 102 until such time as the valve opens, at which time step 103 of the process occurs. In step 103, an alarm is signaled by a controller 133 (Fig. 7) provided as a part of the control system (Fig. 7) for the device. Once the alarm is sounded, the valve location is reported in step 105, again by the controller 133. At the same time, as shown in step 106, a timer is started within the controller, whereupon the subroutine illustrated in steps 107 through 111 begins.

In step 107, the subroutine polls the detection assembly, 30 or 80, respectively, to determine whether the valve is in an open position as compared to the base position. If the valve is open, a record is made of the time that the valve is open until such time as the valve is shown to be closed in step 110. A report of the duration of the time during which the valve was

open is made by the controller. The timer is stopped in step 111 once it has been determined the valve has moved back into its base or closed position.

The other step initiated in step 106, along with starting the timer, is indicated at step 113 where the amount of the valve opening is measured. This can not be done with the second embodiment of the pressure relief valve monitoring device 55 shown in Figs. 3 and 4, for the reasons described above, namely that the reed switch 90 does not provide a proportionate position signal with respect to the position of the piston 73, piston guide stem 75, and the actuating rod 89/metal core 89' with respect to the reed switch, whereas the LVDT 40 can measure the "degree" to which the piston 23 of the valve assembly 19 has opened when the valve is relieving fluid pressure within the system. Accordingly, for the second embodiment of the invention, namely the pressure relief valve monitoring device 55 shown in Figs. 3 and 4, the process skips from step 106 to step 123, and reports the end of the event and the amount of time during which the valve was open.

Referring now to steps 113 through 125, which steps occur with the process practiced by the first embodiment of the pressure relief valve monitoring device 5 of Figs. 1 and 2, in step 113 the amount of the valve opening is determined by measuring or comparing the position signal emitted in the base position and the at least one open position, or range of open positions, as measured by the detection assembly 30. In step 114, based on a pre-programmed data table stored as a part of or otherwise made available to the controller 133 (Fig. 6 and 7), the process queries whether the valve is simmering or is in a full blow condition. Thus, in step 114, if the valve is simmering, the simmer is reported in step 115. Likewise, if the valve is not simmering, then the valve is in a full blow condition which is reported at step 117.

Simultaneously, in step 119 the fluid flow rate through the valve is determined. This subroutine is illustrated in greater detail in Fig. 6. Referring now to Fig. 6, the base position of the valve, *i.e.* the valve's position in its closed or seated position, is read in step 127, which position data, the frequency and amplitude of the signal emitted by the LVDT, is then stored in a database 128 as illustrated in Fig. 6. The detection assembly 30 is polled by the system in step 129 to read to the open position of the valve, when at least one "open" position is detected, and this information is also relayed to the controller/control system such that the open position of the valve assembly 19 with respect to the base position thereof is compared for determining the amount that the valve is open. The controller then reads from a database of values and a flow rate is determined and used by the controller in association with the time the valve is open to determine the volume of fluid lost, *i.e.* the volume of fluid passed, through the relief valve during its relief or over-pressure state.

Referring now to Fig. 5, after reporting the flow rate in step 120, the process proceeds to step 121 to once again poll whether the valve is open. If the valve is open then the subroutine loops back on itself to step 119 to continuously determine and report the flow rate. Once the valve is closed, the process moves forward to step 123 and reports the end of the event to the controller 133 of Fig. 7, whereupon the process loops back to step 102 to see if the valve is open awaiting the next over-pressure event, should one occur.

The reported flow rate of step 120 is used by the controller for calculating the fluid loss in step 124. The volume of the fluid loss may be calculated and reported concurrently during the time in which the valve is open, or may be calculated at the conclusion of the over-pressure event, as desired. Simultaneously with this, the time during which the valve assembly/piston was in an open position, or positions, is reported from step

107 to step 124, whereupon the fluid flow rate and the time that the valve is open are used for determining the volume of fluid passed through the valve, which volume is reported in step 125.

It is understood by those skilled in the art that each one of the blocks shown in Figs. 5 and 6 represents a block of executable program code, which may be programmed in any suitable programming language or format.

Referring now to Fig. 7, the control system of the pressure relief valve detection and monitoring system is schematically illustrated. The pressure relief valve monitoring device 5, 55, respectively, having the detection assembly 30, 80, respectively, sends a constant position signal to the controller 133 of the system. The controller 133 will have a suitable processor or microprocessor 134 provided as a part thereof, and access through a data buss to a random access memory ("RAM") 135, and/or a read only memory ("ROM") 137, as well as to the devices discussed hereinbelow.

The system also includes a power supply 138, which powers not only the controller 133, but also the respective embodiments of the detection assemblies 30,80. The control system also has a data input and output device 139, which may, for example, be a keyboard, a memory card, a floppy disk, a hard drive, a CD ROM, or DVD, or other known forms of data input and output devices and methods. The system is also provided with a data storage and retrieval device 141, which again may be one of the above described data storage devices, as well as a data display 142. The system may also be provided with a printer 143 for printing a report of an over-pressure event when it occurs, as well as an annunciator 145 for signaling an audible alarm when the relief valve is relieving an over-pressure condition.

While from the description hereof it may appear that either of the first, the second, or the third embodiments of the pressure relief valve monitoring devices 5, 55, 155, respectively may be used in the detection and monitoring system of the invention, it is anticipated that pressure relief valve monitoring and detection systems could be developed using several of the embodiments of the relief valve monitoring device of the invention. For example, it is possible that the first or the third embodiment of the pressure relief valve monitoring device 5, 155, respectively, could be used with a pressurized mechanical refrigeration system, whereas a second series of pressure relief monitoring devices 55 could be used for pressurized steam or water systems also found within the same plant, both of which report to a common control system for preparing the requisite reports, the need for reporting how much steam or water having flowed through a relief valve perhaps not being as important, for example, as the amount of ammonia passing through a refrigeration system.

Moreover, it is possible that a "blended" system using any desired one of the embodiments of the devices 5, 55, 155, of the invention in the same system could be developed where all that is needed in some locations is merely to know whether a specific valve has been opened, and in other locations there may be a need to precisely determine how much fluid has been passed from the fluid distribution system. Also, it can be appreciated that the pressure relief valve detection and monitoring devices and system of this invention, and the methods practiced therewith, may be used in applications other than with pressure relief valves, namely the invention may be employed anywhere there is a need to determine whether a valve has opened, the location of the valve within a fluid distribution system that has been opened, and the volume of fluid, either liquid or gas, that has passed through the valve or valves of the system.

Although not shown in Fig. 7, a separate annunciator 145 may be provided for each pressure relief valve, if so desired. Additionally, and at a minimum, a common or shared annunciator will be positioned at a control station in which the control system of Fig. 7 is in use for alerting a plant operator or operators of the actuation of a pressure relief valve or valves.

The system of Fig. 7 will record the following criteria whenever a pressure relief valve actuates, the location or identity of the valve within the system, how long the valve has been open, and will sound an alarm. When the first embodiment of the device 5 is used with this system, the system will also record the position of the valve with respect to its base position, will determine the fluid flow rate, and will calculate the amount of fluid loss, *i.e.* the volume of fluid passed through the valve during the over-pressure event. As described in the process of Fig. 5, the first embodiment of the device 5 can also determine whether the valve is merely simmering, or has had a full blow event, in which far greater amounts of fluid have been passed from outside the system.

Rather than using the linear variable differential transformer in the embodiment 5 of the invention illustrated in Figs. 1 and 2, there exist a number of other measuring and signaling devices which are constructed to measure and report a base position signal and at least one subsequent position signal proportionate to the at least one open position of the piston guide stem or the valve assembly. These devices, each of which it is envisioned can be used with the method and device of this invention include, but are not limited to, a capacitive measurement device, a draw wire, an infrared measuring device, a light bar, an optical encoder, a piezoelectric or a piezoresistive (acceleration, or force or pressure) measurement devices, a quartz beam device, a reflective laser or encoder, a linear or a rotational potentiometer, a video displacement device, and/or a variable resistive vector transducer.

Fig. 8 is an illustration of a third embodiment of the device 155 of the invention, in which a linear potentiometer is used in place of the LVDT of the device in Figs. 1 and 2. The device 155 has a pressure relief valve 157 with a valve body 158, an inlet port 159, and a spaced outlet port 161, respectively, defined within the wall of the valve body. A fluid flow path 162 is defined within the valve body and extends between the respective inlet and outlet ports. A cap 163 is threadedly affixed to the valve body at an upwardly extending barrel-like portion. A valve assembly 165 is supported within the fluid flow path of the valve body, and is shown in its closed position in Fig. 8 A.

The valve assembly is adapted for moving into at least one open position, and preferably a range of open positions proportionate to the pressure of the fluid being passed therethrough in the event of an over-pressure event, as described above. The valve assembly has a valve seat 166 positioned within the valve body, with a piston 167 having a piston seat 169 received on the valve seat. The piston has an elongate piston guide stem 170 projecting in a longitudinal/axial direction toward and through an adjusting gland 171 constructed in fashion identical to the adjusting gland 27 of Figs. 1 and 2. A spring 173 is disposed about the piston guide stem 170, and bears against the adjusting gland and the piston for the purposes of forcing the piston seat into engagement with the valve seat and seals the piston within the fluid flow path so that fluid does not normally pass through the relief valve. The pressure relief valve 157 and the valve assembly 165 provided as a part thereof are otherwise conventional, and thus are not described in greater detail.

The relief valve monitoring device 155 includes a detection assembly 174 mounted to the valve body. The detection assembly has an elongate housing 175 affixed to the cap 163 of the valve body, the housing having an elongate bore or chamber 177 defined therein and extending for

substantially the length of the housing. An opening defined in the housing and at the end of the bore is placed in registry with an opening 178 defined in the valve cap. An elongate actuating rod 179 is operably coupled to the free end of the piston guide stem.

The valve assembly 165 is constructed and arranged to move into at least one open position in response to the release of fluid through the valve when the fluid pressure forces the piston to unseat against the compressive force of the spring 173. The valve assembly thus has a range of open positions proportionate to the force of the fluid passed through the relief valve.

The piston guide stem is passed through the adjusting gland 171 and into the bore of the housing so that the rod 179 protrudes through the opening 178 defined in the cap, and extends at least partially into and along the length of the bore 177 defined within the housing. The rod 179 positions a contact wiper 181, the wiper being formed or positioned at the free end of the rod, within the bore of the housing. The bore of the housing acts, therefore, as a wiper receiving chamber. As shown in Figs. 8 A and B, a series of windings 182 are formed (wound) along substantially the length of the housing about the wiper receiving chamber to form a linear potentiometer 183.

In fashion similar to the LVDT of the first embodiment of the invention, the linear potentiometer measures an electrical potential caused by the position of the wiper ring within the bore/wiper receiving chamber of the housing and in engagement with the windings 182. The linear potentiometer has an electrical connection 185, and is powered by the power source 138 of Fig. 7. The linear potentiometer, *i.e.*, the contact wiper and the windings, develops an output signal of a first measured resistance level and amplitude having a specific resistance level and amplitude, or "signature" in the base or closed position of the relief valve.

When the contact wiper 181 moves within the housing, which occurs when the piston and the piston guide stem move along their longitudinal axes away from the valve seat to allow pressurized fluid to pass through the valve body during a over-pressure event into "at least one open position," the contact wiper changes its position with the windings 182 of the potentiometer, which thus creates a change in the measured output resistance level and amplitude measured by the potentiometer, which has the effect of creating a unique position signal separate and apart, *i.e.* distinct, from the base position signal. Thereafter, the base position signal and the at least one open position signal are used in the same manner, and for the same purposes, as described above for the device 5 of Figs. 1 and 2, as well as in the process of Figs. 5 and 6, and the control system of Fig. 7.

Although several embodiments of the invention have been disclosed in the foregoing specification, it is understood by those skilled in the art that many modifications and other embodiments of the invention will come to mind to which the invention pertains, having the benefit of the teaching presented in the foregoing description and associated drawings. It is thus understood that the invention is not limited to the specific embodiments disclosed herein, and that many modifications and other embodiments of the invention are intended to be included in the scope of the appended claims. Moreover, although specific terms are employed herein, as well as in the claims, they are used in the generic and descriptive sense only, and not for the purposes of limiting the described invention, nor the claims which follow.

**What is claimed is:**

1. A pressure relief valve monitoring device for use within a pressurized fluid system, comprising:

a valve body, said valve body having an inlet port and a spaced outlet port defined therein, respectively;

a fluid flow path defined within and extending through the valve body in communication with said inlet and outlet ports, respectively;

a valve assembly housed within said valve body and positioned within said fluid flow path, said valve assembly having a first closed position in which fluid does not flow through the valve body, and at least one open position in which fluid is permitted to pass through the valve body; and

a valve position monitoring device disposed on said valve body, said device being constructed and arranged to generate a position signal when the valve assembly has moved into said at least one open position.

2. The device of claim 1, said monitoring device comprising a housing mounted on the valve body, and an actuating mechanism positioned with respect to said housing, said actuating mechanism being constructed and arranged to move with respect to said housing in response to the movement of said valve assembly from said closed position into said at least one open position.

3. The device of claim 2, wherein said actuating mechanism comprises an elongate rod operably coupled to said valve assembly and extending at least partially within said housing, said rod being supported for movement within said housing, and a ferrous metal core carried on said rod.

4. The device of claim 3, further comprising a reed switch positioned on said housing with respect to said metal core.

5. The device of claim 4, said reed switch being held in a first position when said valve assembly is in its closed position, and being constructed and arranged to move into a second position in response to the movement of said metal core by said actuating mechanism and to emit said position signal in response to being moved into said second position.

6. The device of claim 1, said monitoring device being constructed and arranged to emit a first position signal when the valve assembly is in its closed position, and to emit a second position signal when said valve assembly is moved into said at least one open position.

7. The device of claim 6, said monitoring device comprising a linear variable differential transformer.

8. The device of claim 6, said monitoring device comprising a linear potentiometer.

9. The device of claim 6, said monitoring device being constructed and arranged to emit the second position signal as a proportionate signal correlating to the position of the valve assembly in said at least one open position with respect to the first position signal of the valve assembly while in its closed position.

10. The device of claim 6, said monitoring device being constructed and arranged to continuously emit said second position signal.

11. The device of claim 1, the at least one open position of the valve assembly comprising a range of open positions proportionate to the flow of fluid through the valve assembly.

12. The device of claim 1, said monitoring device being constructed and arranged to determine if said valve assembly becomes reseated after having been moved into said at least one open position.

13. A pressure relief valve monitoring device for use in a pressurized fluid system, comprising:

a valve body having an inlet port and a spaced outlet port defined therein, respectively;

a fluid flow path defined within and extending through the valve body in communication with said inlet and outlet ports, respectively;

a valve assembly housed within said valve body and positioned within said fluid flow path, said valve assembly having a first closed position in which fluid does not flow through the valve body, and at least one open position in which fluid is permitted to pass through the valve body; and

a valve position monitoring device disposed on said valve body, said device being constructed and arranged to generate a first position signal when the valve assembly is in its closed position, and to generate a second position signal in response to the movement of said valve assembly into said at least one open position.

14. The device of claim 13, said monitoring device being constructed and arranged to emit said second position signal as a proportionate signal correlating to the position of the valve assembly in said at least one open position with respect to the first position signal of the valve assembly when in said closed position.

15. The device of claim 13, said monitoring device being constructed and arranged to continuously emit said second position signal.

16. The device of claim 13, said monitoring device comprising a housing mounted on the valve body, and an actuating mechanism positioned with respect to said housing, said actuating mechanism being constructed and arranged to move with respect to said housing in response to the movement of the valve assembly from said closed position into said at least one open position.

17. The device of claim 16, said monitoring device comprising a linear variable differential transformer constructed and arranged to emit said first position signal when the valve assembly is in its closed position, and to emit said second position signal when the valve assembly is moved into said at least one open position.

18. The device of claim 16, said monitoring device comprising a linear potentiometer constructed and arranged to emit said first position signal when the valve assembly is in its closed position, and to emit said second position signal when the valve assembly is moved into said at least one open position.

19. The device of claim 16, said actuating mechanism being constructed and arranged to move linearly with respect to said monitoring device in response to the movement of the valve assembly from said closed position into said at least one open position.

20. The device of claim 16, wherein said actuating mechanism comprises an elongate rod operably coupled to said valve assembly and extending at least partially within said housing, said rod being supported for movement within said housing.

21. The device of claim 13, said valve assembly comprising a piston positioned within the fluid flow path, an elongate piston guide stem seated on said piston, means for guiding said stem within said valve body in response to the movement of the piston from said closed position into said at least one open position, and a spring bearing against the piston for biasing the piston into said closed position.

22. The device of claim 21, said monitoring device being constructed and arranged to measure the movement of said piston guide stem in response to the movement of said piston from said closed position into said at least one open position.

23. The device of claim 21, said monitoring device comprising a housing mounted on the valve body, and an actuating mechanism positioned with respect to said housing, said actuating mechanism being constructed and arranged to move with respect to said housing in response to the movement of said piston from said closed position into said at least one open position.

24. The device of claim 23, said actuating mechanism comprising an elongate rod extending at least partially within said housing and being supported for linear movement therein in response to the movement of said guide stem.

25. The device of claim 24, said housing comprising a linear variable differential transformer constructed and arranged to emit a first position signal when the valve assembly is in said closed position, and to emit a second position signal when the valve assembly is moved into said at least one open position.

26. The device of claim 24, said housing comprising a linear potentiometer constructed and arranged to emit a first position signal when the valve assembly is in said closed position, and to emit a second position signal when the valve assembly is moved into said at least one open position.

27. The device of claim 13, said at least one open position of the valve assembly comprising a range of open positions responsive to fluid flow through the valve body, said monitoring device emitting a unique one of said second position signals in cooperation with said core for each open position of the valve assembly in said range of open positions.

28. The device of claim 13, said monitoring device being constructed and arranged to determine if said valve assembly moves back into said closed position after having been moved into said at least one open position.

29. A pressure relief valve monitoring system, said system comprising:

i) a pressure relief valve, said valve having:

a valve body having an inlet port and a spaced outlet port defined therein, respectively;

a fluid flow path defined within and extending through the valve body in communication with said inlet and outlet ports, respectively; and

a valve assembly housed within said valve body and positioned within said fluid flow path, said valve assembly having a first closed position in which fluid does not flow through the valve body, and at least one open position in which fluid is permitted to pass through the valve body;

ii) a valve position monitoring device disposed on said valve body, said device being constructed and arranged to generate a first position signal when the valve assembly is in its closed position, and a second position signal in response to the movement of the valve assembly into said at least one open position; and

iii) a control system operably coupled to said valve position monitoring device.

30. The system of claim 29, said control system being constructed and arranged to compare said second position signal to said first position signal for determining the extent to which the valve assembly has opened in response to the flow of fluid through the valve body.

31. The system of claim 29, said control system being constructed and arranged to measure the period of time during which the valve assembly is in said at least one open position.

32. The system of claim 29, said control system being constructed and arranged to determine the rate of fluid flow through the valve assembly during the time in which the valve assembly is in said at least one open position.

33. The system of claim 29, said control system being constructed and arranged to determine the volume of fluid passed through the valve assembly during the time in which the valve assembly is in said at least one an open position.

34. The system of claim 29, further comprising at least one data input device coupled to a controller.

35. The system of claim 29, further comprising at least one data storage and retrieval device coupled to a controller.

36. The system of claim 29, further comprising a data display device coupled to a controller.

37. The system of claim 29, further comprising an annunciator coupled to a controller.

38. A method of monitoring a pressure relief valve used in a pressurized fluid system having at least one pressure relief valve, the at least one pressure relief valve having a valve body with an inlet port and a spaced outlet port defined therein, respectively, a fluid flow path defined within and extending through the valve body in communication with the respective inlet and outlet ports, a valve assembly housed within the valve body and positioned within the fluid flow path, the valve assembly having a first closed position in which fluid does not flow through the valve body, and at least one open position in which fluid is permitted to pass through the valve body, and a valve position monitoring device disposed on said valve body, comprising the steps of:

i) generating a first position signal with the valve position monitoring device when the valve assembly is in its closed position;

ii) monitoring the position of the valve assembly; and

iii) generating at least a second position signal in response to the movement of the valve assembly into the at least one open position thereof.

39. The method of claim 38, comprising the step of continuously monitoring the position of the valve assembly.

40. The method of claim 38, comprising the step of continuously reporting said at least a second position signal to a controller.

41. The method of claim 40, comprising the step of continuously recording said at least a second position signal within said controller.

42. The method of claim 38, comprising the step of recording the duration of the time period during which the valve assembly is within its at least one open position.

43. The method of claim 38, comprising the step of determining the flow rate of the fluid passed through the valve assembly while the valve assembly is in its at least one open position.

44. The method of claim 38, comprising the step of determining the volume of the fluid passed through the valve assembly in its at least one open position.

45. The method of claim 38, comprising the step of sounding an alarm while the valve assembly is in its at least one open position.

46. The method of claim 38, comprising the step of reporting the identity of the at least one pressure relief valve within the pressurized fluid system of which the valve assembly thereof has moved into its at least one open position.

47. The method of claim 38, comprising the step of reporting the location of the at least one pressure relief valve within the pressurized fluid system of which the valve assembly thereof has moved into its at least one open position.

48. The method of claim 38, comprising the step of determining if the valve assembly moves back into its closed position after having been moved into its at least one open position.

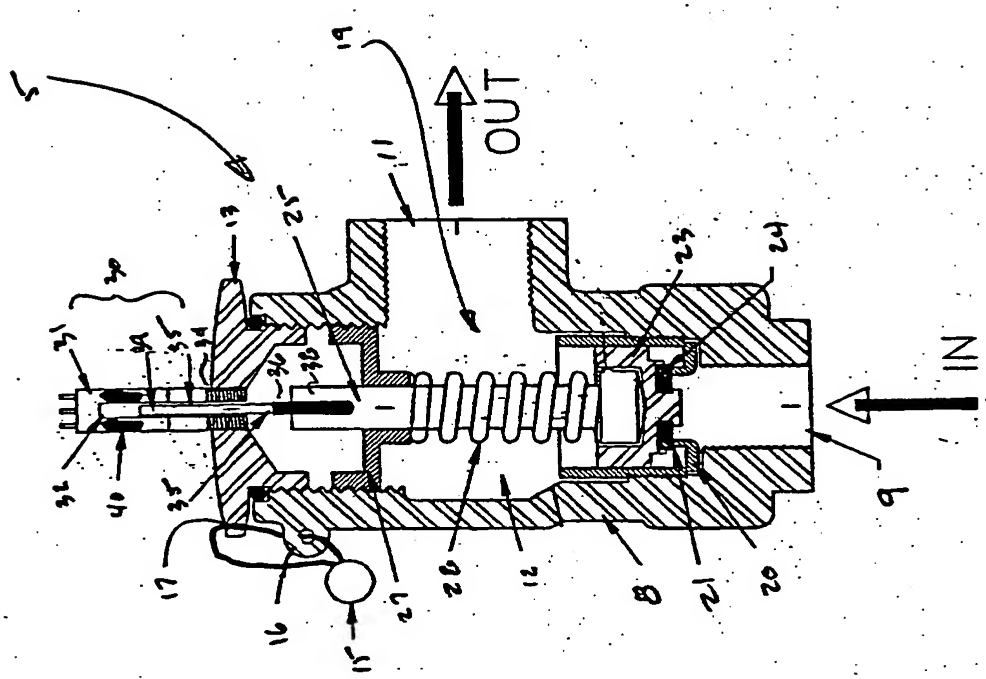



Fig. 2

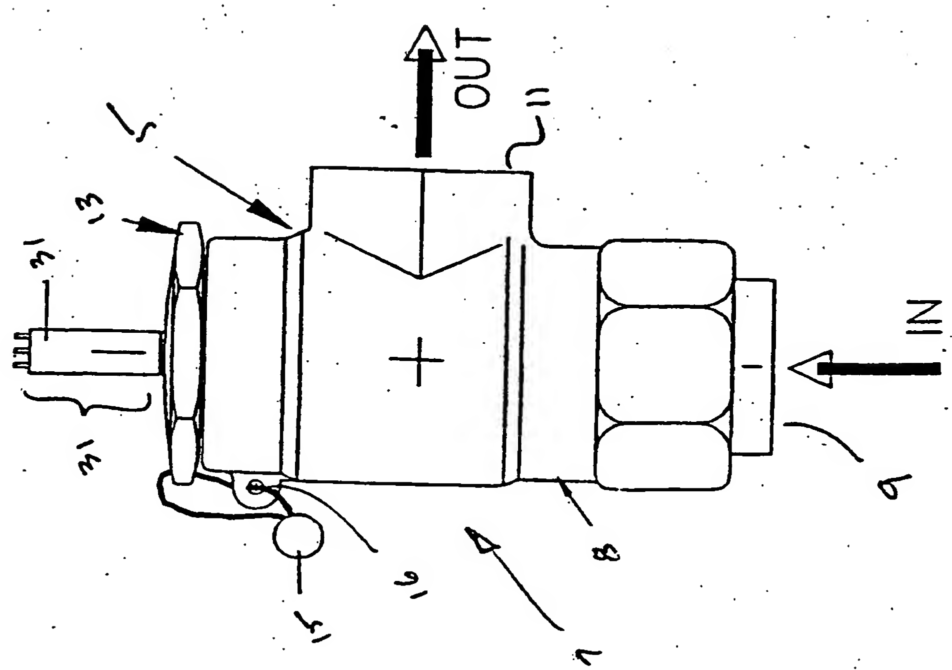



Fig. 1

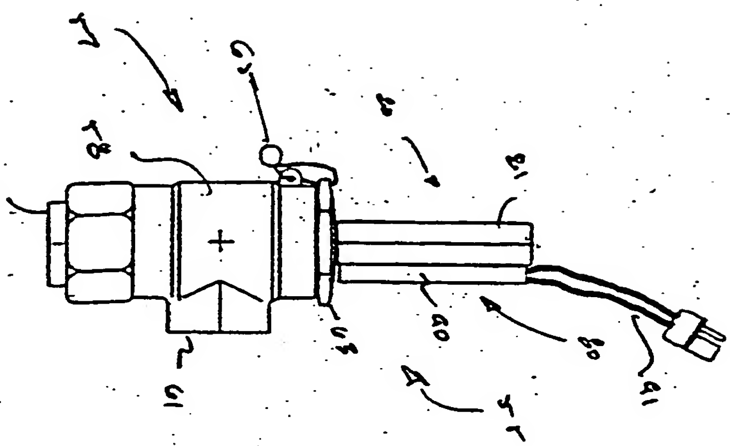


Fig. 3

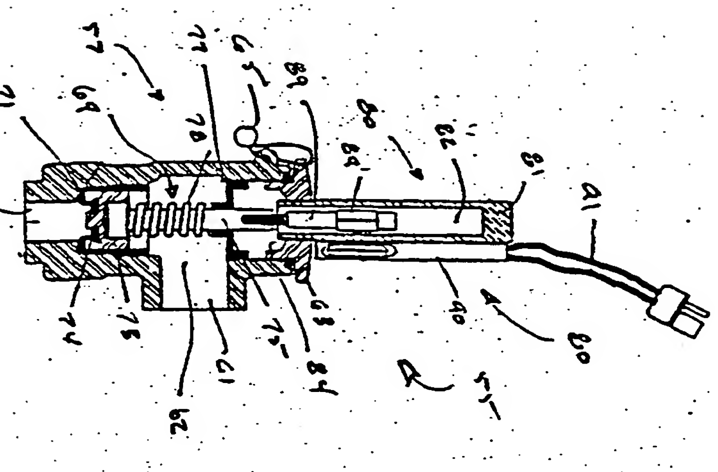


Fig. 4

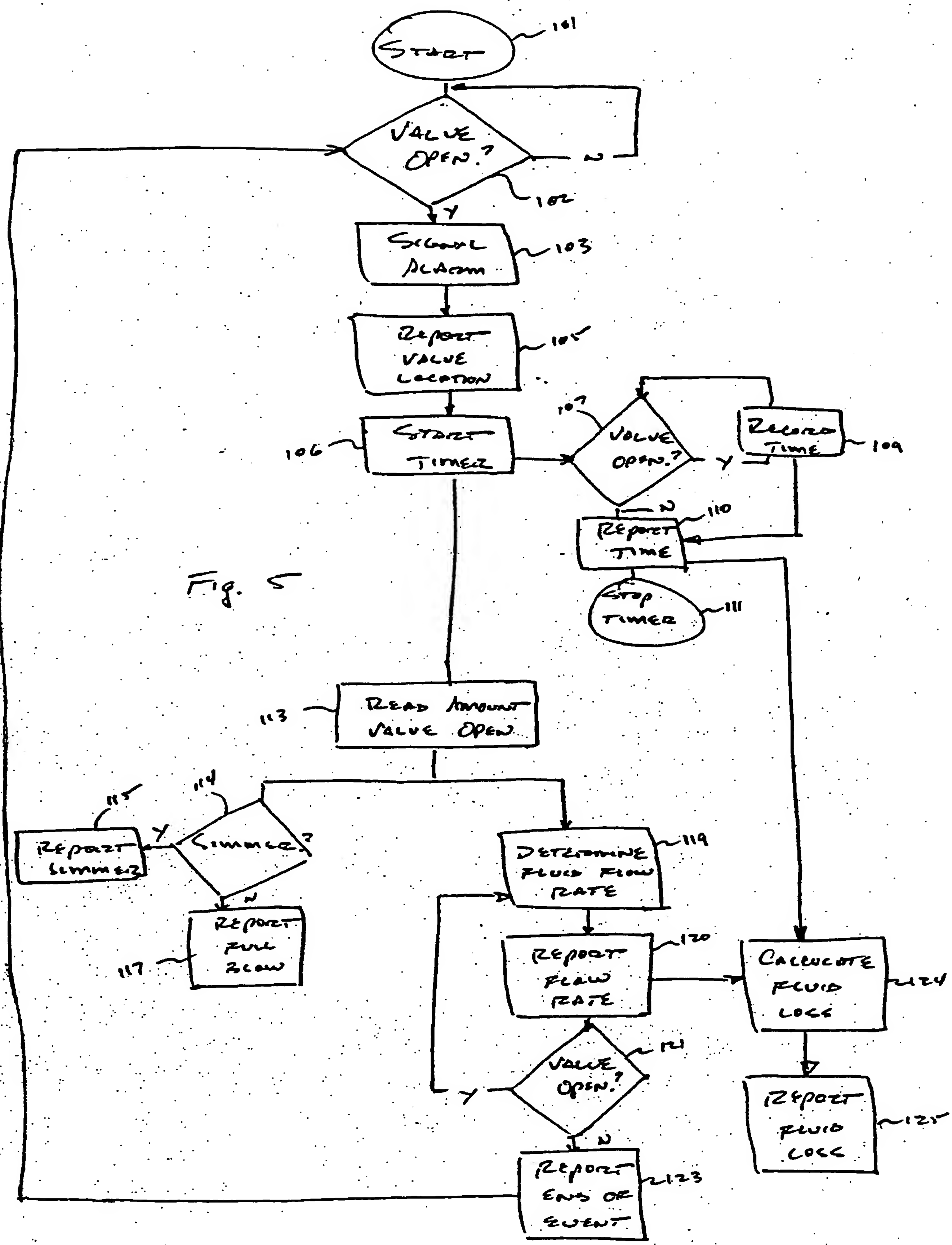

START
101
VALVE OPEN?
102
N
Y
SIGNAL ALARM
103
REPORT VALVE LOCATION
105
START TIMER
106
107
VALVE OPEN?
Y
N
RECORD TIME
109
REPORT TIME
110
STOP TIMER
111
READ AMOUNT VALVE OPEN
113
114
SIMMER?
Y
N
115
REPORT SIMMER
REPORT FULL FLOW
117
DETERMINE FLUID FLOW RATE
119
REPORT FLOW RATE
120
VALVE OPEN?
121
Y
N
REPORT END OF EVENT
123
CALCULATE FLUID LOSS
124
REPORT FLUID LOSS
125

Fig. 5

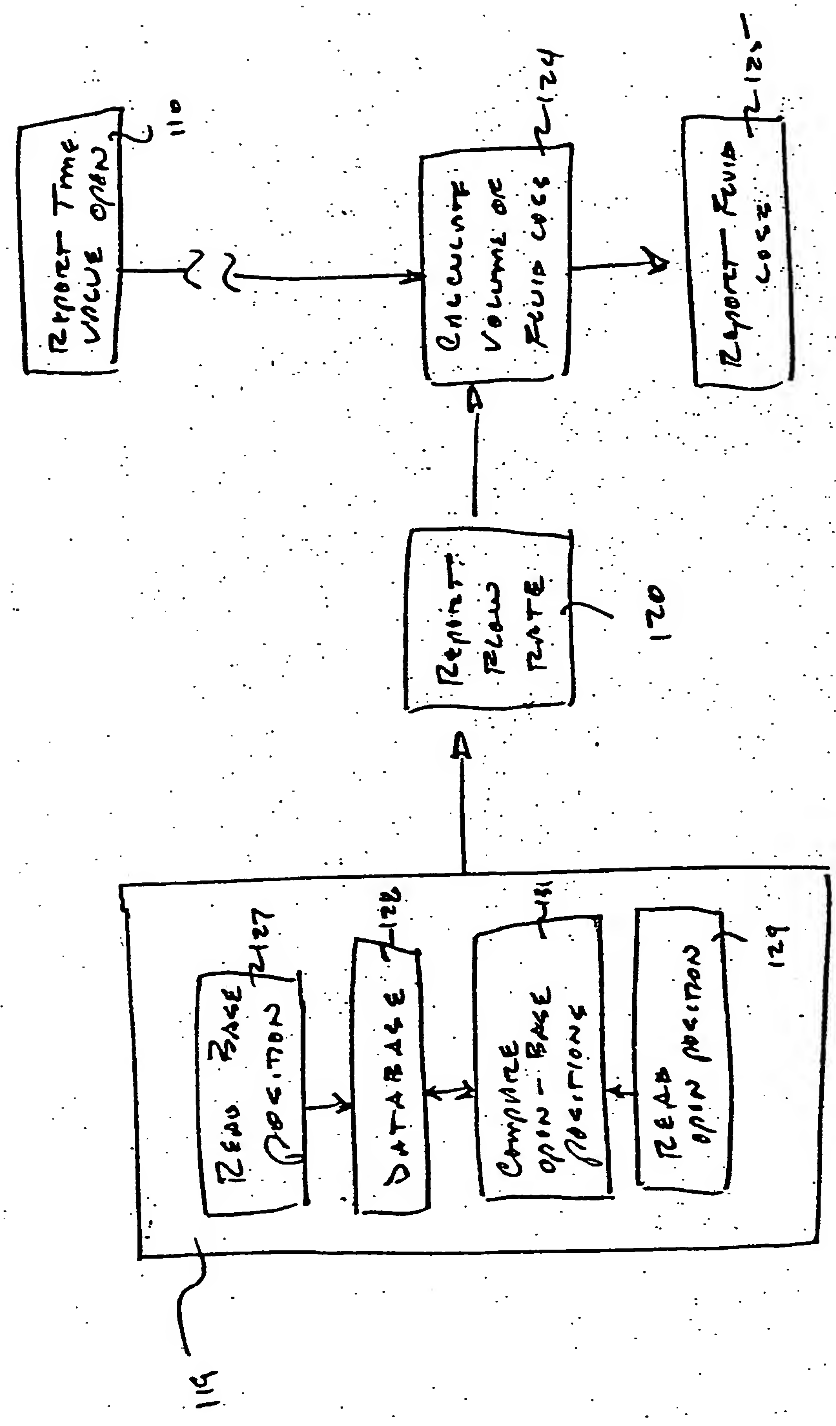

Report Time Valve Open
110
Calculate Volume of Fluid Loss
124
Report Fluid Loss
125
Report Flow Rate
120
Read Base Position
127
Database
128
Compare Open-Base Positions
131
Read Open Position
129
119

Fig. 6

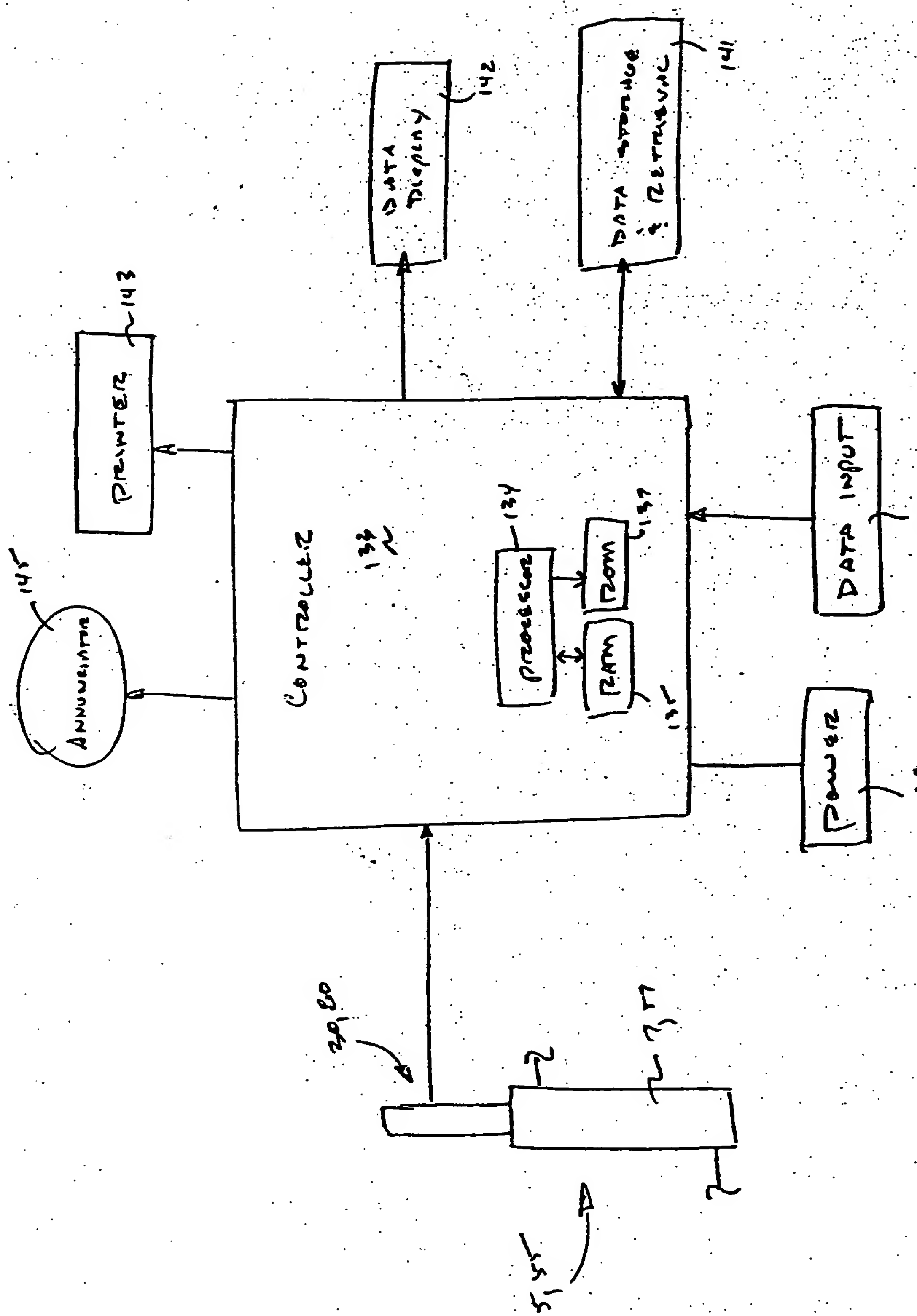

CONTROLLER
PROCESSOR
ROM
RAM
PRINTER
ANNUNCIATOR
DATA DISPLAY
DATA STORAGE & RETRIEVAL
DATA INPUT
POWER
143
145
142
141
134
138
139

Fig. 7

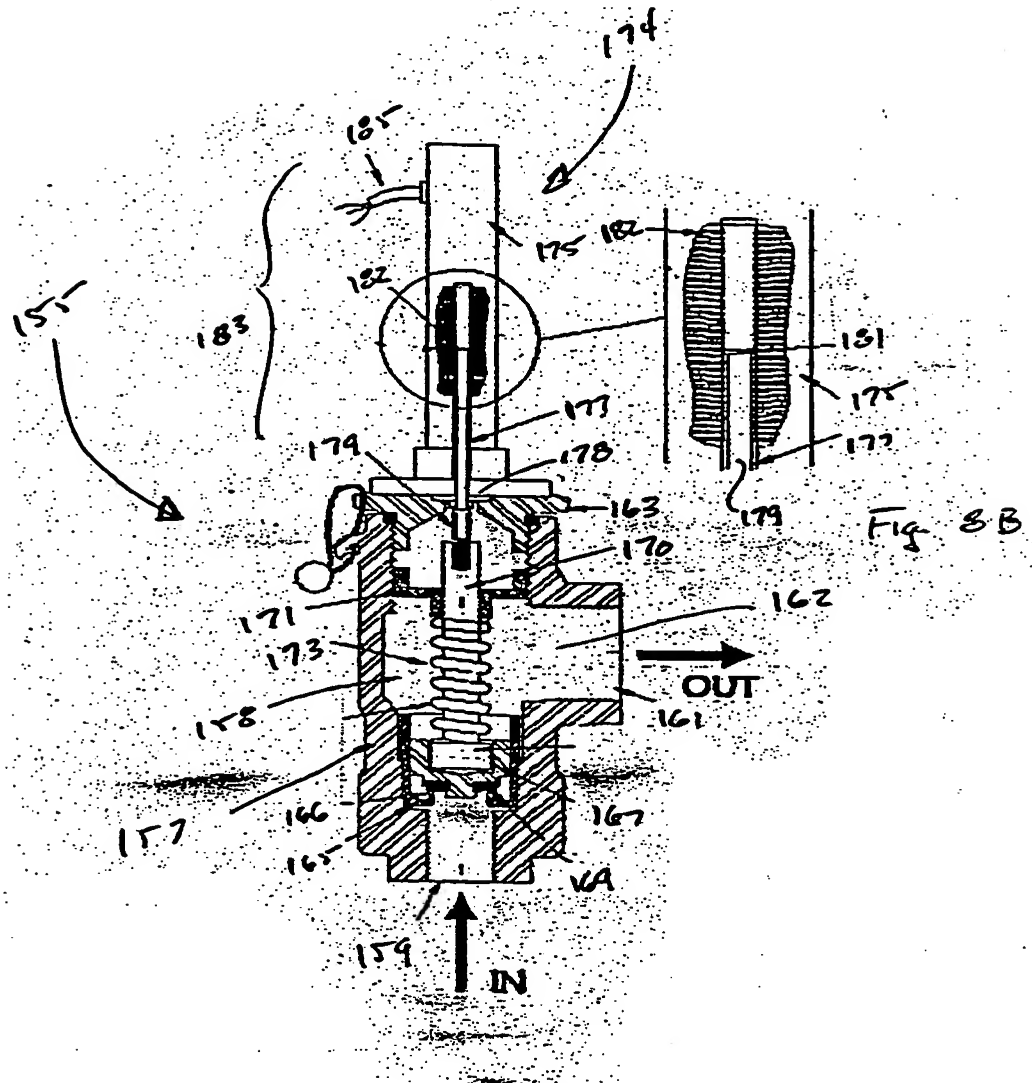

174
185
175
182
183
155
181
175
177
179
178
163
179
170
171
162
173
OUT
158
161
157
166
167
165
169
159
IN

Fig. 8B

Fig. 8A

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 June 2001 (14.06.2001)

PCT

(10) International Publication Number
WO 01/42693 A3

(51) International Patent Classification[7]: F16K 17/04, 37/00

(21) International Application Number: PCT/US00/42566

(22) International Filing Date: 5 December 2000 (05.12.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

| | | |
|---|---|---|
| 60/170.030 | 10 December 1999 (10.12.1999) | US |
| 60/171.174 | 16 December 1999 (16.12.1999) | US |
| 09/684.537 | 6 October 2000 (06.10.2000) | US |

(71) Applicant (*for all designated States except US*): BARROW FINANCIAL ASSOCIATES [—/US]; 3506 East Highway 16, P.O. Box 99, Sharpsburg, GA 30277 (US).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): BARROW, William, E. [—/US]; 20 Mattox Road, Newnan, GA 30263 (US). BARROW, Michael, A. [—/US]; 120 Riverside Court, Sharpsburg, GA 30277 (US). BYRD, David, E. [—/US]; 440 McBride Road, Fayetteville, GA 30215 (US).

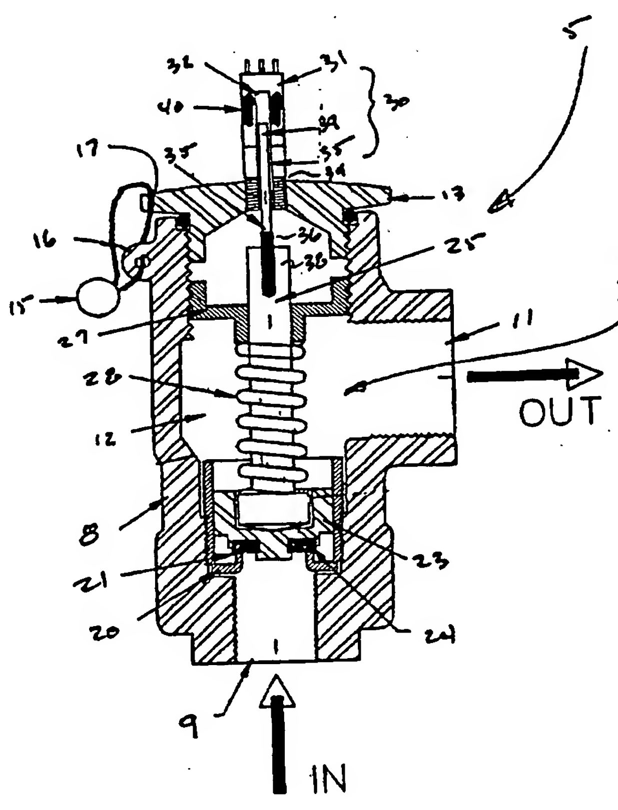
(74) Agents: FAILS, Charles, H. et al.; Needle & Rosenberg, P.C., Suite 1200, 127 Peachtree Street, N.E., Atlanta, GA 30303-1811 (US).

(81) Designated States (*national*): AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian

*[Continued on next page]*

(54) Title: PRESSURE RELIEF VALVE DETECTION AND MONITORING DEVICE AND SYSTEM




(57) Abstract: A pressure relief valve detection and monitoring device (5, 55, 155), system, and method are disclosed. The device includes a pressure relief valve (7, 57, 157) having a valve assembly (19, 69, 165). The valve assembly has a first closed position, and at least one open position in which fluid is permitted to pass through the valve. A valve position monitoring device is disposed on the valve body (8, 58, 158) and is adapted to generate a position signal when the valve assembly is moved into the at least one open position. The monitoring device includes a housing (31, 81, 175) mounted on the valve body, and an actuating mechanism positioned with respect to the housing and is adapted to move with respect to the housing in response to the movement of the valve assembly from its closed position into its at least one open position. In a first embodiment the valve position monitoring device (5) comprises a linear variable differential transformer (40) adapted to emit a second position signal in response to the valve being moved into the at least one open position. In a second embodiment the valve position monitoring device (55) comprises a reed switch (90) adapted to signal when the valve assembly (69) is moved out of its closed position. In a third embodiment the valve position monitoring device (155) comprises a linear potentiometer (183) adapted to emit a second position signal in response to the valve being moved into the at least one open position.

WO 01/42693 A3

patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published:**

— *with international search report*

**(88) Date of publication of the international search report:** 7 February 2002

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/42566

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 F16K17/04 F16K37/00

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP 0 933 571 A (SIEMENS ELEMA AB) 4 August 1999 (1999-08-04)<br>column 4, line 16 -column 5, line 6<br>figure 2<br>--- | 1-3,6, 9-16,20, 27-30, 37-41,48 |
| X | US 5 323 142 A (FAIN JOHN E) 21 June 1994 (1994-06-21)<br>column 5, line 3 - line 45<br>figure 1<br>---<br>-/-- | 1-3,6, 9-16, 20-24, 27-30, 35-40,48 |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 2 October 2001 | 09/10/2001 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Ceuca, A-N |

# INTERNATIONAL SEARCH REPORT

Inter 'onal Application No
PCT/US 00/42566

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication,where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 4 557 136 A (GREENHALF EDWARD J) 10 December 1985 (1985-12-10)<br>column 3, line 47 - line 58<br>column 3, line 47 -column 4, line 44<br>figure 1 | 1-3,6,9, 13,14, 16, 20-24, 29-31, 35,37-42 |
| X | US 4 349 885 A (THOMPSON LEONARD J) 14 September 1982 (1982-09-14)<br>column 3, line 24 -column 4, line 40<br>column 5, line 4 - line 17<br>figures 1,2 | 1-3,6,7, 9-17, 19-25, 27-31, 34-42, 45,48 |
| X | EP 0 051 961 A (CROSBY VALVE & GAGE) 19 May 1982 (1982-05-19)<br>page 6, line 7 -page 7, line 10<br>page 7, line 30 -page 8, line 13<br>figure 2 | 1,2,6, 11-13, 16,20, 28,38,48 |
| A | | 3-5 |
| A | US 4 198 030 A (JACKSON BYRON L ET AL) 15 April 1980 (1980-04-15)<br>column 3, line 43 - line 62<br>column 4, line 44 -column 5, line 5<br>figure 1 | 1-3,6, 8-16, 18-24, 26-29,38 |

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/42566

| Patent document cited in search report | | Publication date | Patent family member(s) | | Publication date |
|---|---|---|---|---|---|
| EP 0933571 | A | 04-08-1999 | EP | 0933571 A1 | 04-08-1999 |
| | | | JP | 11257516 A | 21-09-1999 |
| | | | US | 6044849 A | 04-04-2000 |
| US 5323142 | A | 21-06-1994 | CA | 2067632 A1 | 18-01-1993 |
| | | | MX | 9204166 A1 | 01-01-1993 |
| US 4557136 | A | 10-12-1985 | CA | 1218915 A1 | 10-03-1987 |
| | | | EP | 0133797 A2 | 06-03-1985 |
| US 4349885 | A | 14-09-1982 | CA | 1132359 A1 | 28-09-1982 |
| | | | DE | 3063731 D1 | 21-07-1983 |
| | | | EP | 0017365 A1 | 15-10-1980 |
| | | | FR | 2452041 A1 | 17-10-1980 |
| | | | JP | 1510061 C | 26-07-1989 |
| | | | JP | 55160827 A | 15-12-1980 |
| | | | JP | 62042196 B | 07-09-1987 |
| EP 0051961 | A | 19-05-1982 | AU | 7674481 A | 20-05-1982 |
| | | | BR | 8107253 A | 27-07-1982 |
| | | | EP | 0051961 A1 | 19-05-1982 |
| | | | ES | 506917 D0 | 16-08-1982 |
| | | | ES | 8206802 A1 | 16-11-1982 |
| | | | JP | 57127185 A | 07-08-1982 |
| US 4198030 | A | 15-04-1980 | NONE | | |